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RESEARCH ARTICLE

A multivariate vegetation analysis of Mahseer National Park, Azad Jammu and Kashmir

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Abstract

This research work targets to evaluate the floristic composition of Mahseer National Park, Azad Jammu and Kashmir (AJK). Field data was recorded from fifteen different sites. The Quadrat method was used for vegetation sampling while the exact location of each site, altitude, exposure and geographical coordinates were documented by using geographical positioning system (GPS). To analyze the significance of environmental variables, multivariate statistical analysis was carried out by using two-way clustering, canonical correspondence analysis (CCA) and general linear model (GLM) response curve analysis. Floristically, 109 plant species belonging to 45 families were recorded. Among families, Poaceae was most commonly distributed, accounting for 15 species in total. Two-way cluster analysis categorized the vegetation into four major plant communities. CCA was used to analyze the vegetation-environment relation. Plant species showed a significant correlation response against altitudinal gradient, total nitrogen, electrical conductivity and calcium contents. The GLM response curve and IVI demonstrated that *Cynodon dactylon* was the most dominant species followed by *Dalbergia sissoo* and *Adhatoda zeylinica*. This study provided the baseline information about the eco-floristic composition. It suggested that the area is floristically rich, and needs to be analyzed in detail by future researchers.

Keywords

AJK, Mahseer, cluster analysis, canonical correspondence analysis (CCA), general linear model (GLM).

Introduction

Vegetation refers to the assemblage of plant species, and the ground cover they provide while the association of these plants in a specific area is termed as plant com-

munity (Andel *et al.*, 1993). In addition to plant diversity, it may comprise of climate and soil that control the flow of various biogeochemical cycles, for example: water, carbon, nitrogen, etc., hence processing great significance in local and global energy balances. These components are related to each other, the variation in any one may cause a change in the associated other component (Uniyal *et al.*,2006). Phytosociology is the assessment and evaluation including physiognomies of plant communities via modest and swiftly employed field practices (Folega *et al.*, 2012). Depending on the vegetation, their structure, distribution, composition and association between species in various regions of the world, different systems of vegetation analysis and classification have evolved (Biondi, 2011). Recently various advanced multivariate statistics e.g. Canonical Correspondence Analysis, Detrended Correspondence Analysis and Two Way Indicator Species Analysis etc. are widely used to describe vegetation complexes throughout the world (Zhang *et al.*, 2014; Badshah *et al.*, 2013; Shah *et al.*, 2013; Shaheen and Shinwari 2012;). Keeping in view the importance of plant resources, the present study aims to quantify the vegetation of Mahseer National Park by using various classical as well as modern multivariate statistical techniques as done by Qureshi *et al.* (2011).

Methods

Azad Jammu and Kashmir (AJK) is rich in plant diversity because of its diverse habitats, such as rivers, lakes, tributaries, springs, pastures and steep slopes, etc. (Khan *et al.*, 2012). The study zone, i.e. Poonch River originates from the western foothills of the Pir Panjal range, Indian held Jammu and Kashmir. It flows to the North West and enters AJK via Line of Control (LOC) where it spans over 11,000 acres of land, and received the status of National Park in 2010. At first, flowing southward it enters Mangla Lake. The towns of Poonch, Tetrinote, Mandhole, Tatta Pani, Reyan, Kotli, Gulpur, Nar, Rajdhani and Palaak, etc., are situated on the bank of this river Fig. 1.

The climate of the area is subtropical, wherein *Dalbergia sissoo* is the dominant tree species. Due to persistently cool and humid atmosphere, phytodiversity in the area consists of a broad variety of trees, herbs, shrubs and climbers. In spite of intensive floristic and vegetation studies throughout AJK, there was still no information on the phytodiversity of Mahseer National Park (Safeer *et al.*, 2017).

Keeping in view the apparent heterogeneity in the vegetation, different sampling sites were marked in the study area. From fifteen different sites field data was recorded and the exact location of each site, altitude, exposure as well as geographical coordinates were documented by using Global Positioning System (GPS). The Quadrat method was taken as a tool for vegetation sampling and phytosociological attributes estimation. In each site, 5 quadrats of $10\times10m^2$ size each for trees, followed by 10 of $5\times5m^2$ each for shrubs, and 20 of $1\times1m^2$ each for herbs were systematically, as well as randomly laid (Safeer *et al.*, 2018). Vegetation parameters like composition, cover, frequency and density were calculated. For a particular species, primary data was then

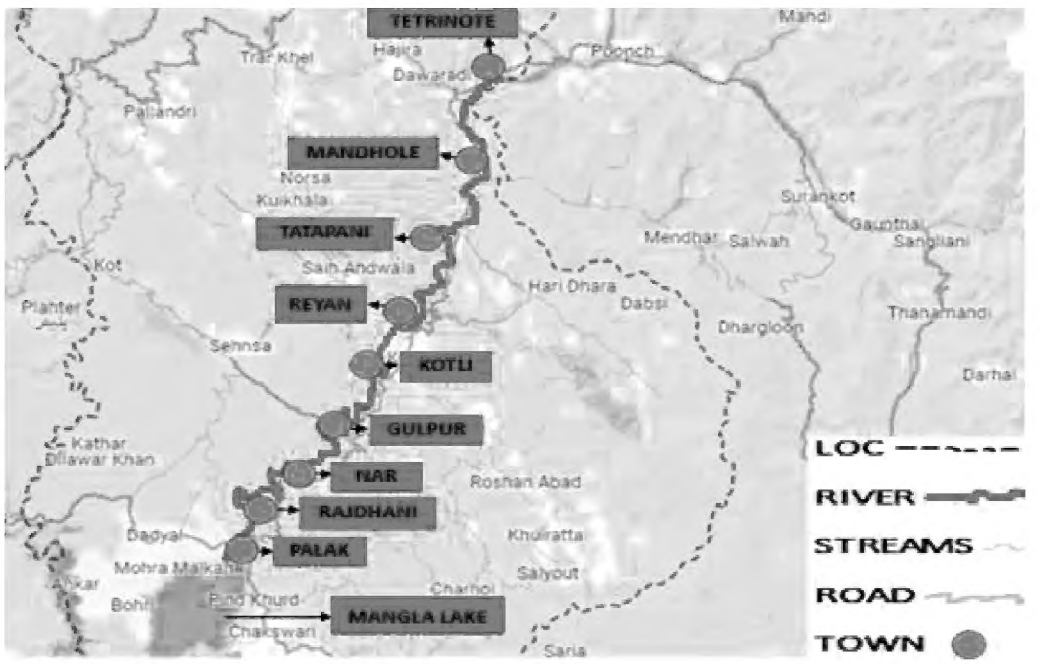

Figure 1. Satellite route map of Mahseer National Park, AJK.

computed to get relative density, relative dominance and relative frequency. These values were aggregated to obtain the importance value index (IVI) which is a measure of how dominant a species is in a given area (Qureshi *et al.*, 2009).

$$Frequency\ \% = \frac{Time\ of\ occurence\ of\ a\ species\ in\ a\ Quadrat}{Total\ number\ of\ Quadrats\ sampled} \times 100$$

$$Density\ \% = \frac{Total\ number\ of\ individuals\ of\ a\ species}{Total\ number\ of\ Quadrats\ sampled}$$

$$Coverage\ \% = \frac{Total\ coverage\ of\ a\ species}{Total\ number\ of\ Quadrats\ sampled}$$

$$Relative\ Frequency\ (R.F) = \frac{Frequency\ value\ of\ a\ particular\ species}{Total\ frequency\ values\ of\ all\ the\ species} \times 100$$

$$Relative\ Density\ (R.D) = \frac{Density\ of\ a\ particular\ species}{Total\ density\ of\ all\ the\ species} \times 100$$

$$Relative\ Cover\ (R.C) = \frac{Coverage\ of\ a\ particular\ species}{Total\ coverage\ of\ all\ the\ species} \times 100$$

$$Importance\ Value\ Index\ (I.V.I) = R.F + R.D + R.C$$

About 1 kg of soil sample was collected from each of the sites up to the depth of 15 cm. The soil's physico-chemical analysis was conducted and the following parameters were determined; water holding capacity and textural analysis (Hydrometer), colour, electrical conductivity (EC meter), pH (pH meter), bulk density, concentration of calcium, magnesium, sulphate, organic matter (Wet combustion method), organic carbon, phosphorus (Olsen method), potassium (Flame photometer) and total nitrogen (Hailu, 2017; Chandra *et al.*, 2016; Maki *et al.*, 2007). To analyze the significance of environmental variables, multivariate statistical analysis was carried out by using TWINSPAN and CANOCO software (Cui *et al.*, 2009; Zheng *et al.*, 2019; Vahdati *et al.*, 2017).

Results

3.1. Floristic composition of Mahseer National Park, AJK

Floristically, 109 plant species belonging to 45 families were recorded from the investigated sites of Mahseer National Park, AJK. Poaceae family was found to be dominant with 15 plant species followed by Lamiaceae (8 species), Asteraceae and Moraceae (6 species each), Solanaceae (5 species), Rosaceae and Amaranthaceae (4 species each) while the rest of the families had contributed only a small number of species. Furthermore, the Importance value index (IVI) showed that *Cynodon dactylon* with IVI 641 was found to be the dominant plant species in the study area followed by *Dalbergia sissoo* with IVI 395 and *Adhatoda zeylanica* with IVI 249 (Table 1).

Table 1. IVI based floristic composition of Mahseer National Park, AJK.

Family	Plant Species	Site Wise Importance Value Index														
Mimosaceae	*Acacia modesta* Wall.	-	-	9.2	-	8.6	8.5	-	-	-	12	25	-	22	6.7	13
	Acacia nilotica (Linn.) Delile.	-	-	-	-	-	-	-	-	-	-	-	2.5	-	-	-
	Albizia chinensis Osbeck.	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-
Amaranthaceae	*Achyranthes aspera* Linn.	4.1	4	8.5	5.6	8.4	-	3.7	6.4	7.7	-	-	-	6.4	-	-
	Alternanthera sessilis Linn.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.4
	Amaranthus spinosus Linn.	-	-	-	-	-	-	-	-	-	-	-	5.9	-	-	-
	Amaranthus viridis Linn.	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-
Simaroubaceae	*Ailanthus excelsa* Roxb.	-	-	-	-	-	-	-	-	11	-	-	6.5	13	-	-
	Ailanthus altissima Mill.	-	-	3.7	-	-	-	-	15	-	-	-	-	-	33	11
Acanthaceae	*Adhatoda zeylanica* Medic.	-	-	6.7	-	37	2.7	47	37	18	-	25	-	24	21	31
	Barleria cristata L.	-	-	-	-	2.5	-	-	-	-	-	-	1.6	-	-	-
Pteridaceae	*Adiantum venustum* D. Don	-	-	-	-	-	-	-	3.5	-	-	3.6	3.6	3.9	-	5.2
Lamiaceae	*Ajuga bracteosa* Wall.	-	-	-	-	2.3	7.5	-	-	-	-	-	1.6	-	4.2	-
	Anisomeles indica (L.) O. Kuntze.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.6
	Calamintha umbrosa M. Bieb.	-	-	-	-	-	2.6	-	-	-	-	-	-	-	-	-
	Mentha longifolia L.	15	6.9	-	5.3	13	7.3	8.8	9.1	-	6.3	-	6.6	-	-	-
	Mentha sylvestris L.	9.5	-	-	4.9	-	-	-	-	-	-	-	-	-	-	-
	Mentha viridis L.	10	7.5	-	-	-	-	7.4	4.4	-	4.1	-	6.6	-	-	-
	Micromeria biflora Ham. ex D. Don	-	-	-	6.9	-	-	-	-	3.4	3.5	3.6	-	-	-	-
	Salvia bucharia M. Popov.	-	-	-	-	-	-	-	1.7	-	-	1.6	-	-	-	-
Araceae	*Arisaema flavum* (Forsk.) Schott.	-	-	-	-	-	-	-	-	-	-	-	-	-	3.3	-
Asparagaceae	*Asparagus filicinus* Ham ex D. Don.	-	-	-	-	-	-	-	-	-	1.6	-	-	-	-	7.2
Berberidaceae	*Berberis lycium* Royle.	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-

Family	Plant Species	Site Wise Importance Value Index														
Poaceae	*Brachiaria ramosa* Linn.	-	-	-	-	0.9	-	-	-	-	-	-	-	-	-	-
	Brachiaria reptans Linn.	-	-	-	-	5.7	-	-	-	-	-	-	-	-	-	-
	Chrysopogon aucheri (Boiss.) Stapf.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.2
	Cymbopogon jwarancusa (Jones.)	-	24	4.3	-	-	-	-	-	-	-	-	-	-	-	-
	Cymbopogon schoenanthus Su. & St.	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
	Cynodon dactylon L.	29	36	41	21	35	33	48	53	39	43	49	52	79	43	40
	Dichantium annulatum (Forsk.) Stapf	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.1
	Digitaria ciliaris (Retz.) Koe.	-	-	-	-	-	-	-	30	-	-	-	-	-	8.3	-
	Imperata cylindrica (Linn.) Raeu.	-	-	2.1	17	-	-	-	-	-	-	-	-	-	8.1	-
	Echinochloa crus-galli Linn.	-	-	-	-	-	-	-	-	-	3.5	-	-	-	-	-
	Phragmites karka (Retz.) Trn ex Std.	-	-	-	-	-	12	7.7	-	-	-	-	-	-	-	-
	Poa annua Linn.	-	23	6.7	7.1	-	6.7	-	-	-	-	-	-	-	-	-
	Saccharum spontaneum L.	-	-	-	-	-	-	-	-	-	20	-	-	-	43	-
	Setaria glauca (L.) Beauv.	-	-	6.2	3.2	-	-	-	-	-	5.7	-	-	-	-	-
	Saccharum giganteum (Walter) Pers.	-	-	-	-	-	-	-	-	25	-	23	32	-	-	43
Cannabaceae	*Cannabis sativa* Linn.	2.7	6.2	4.2	-	-	-	5.1	-	8.6	-	-	4.9	8.3	-	-
Apocynaceae	*Carissa carandas* Linn.	-	-	10	-	13	-	-	19	12	-	13	-	-	-	2.2
	Carissa opaca Stapf ex Haines.	13	-	-	-	-	-	-	-	-	-	-	-	-	14	-
	Nerium indicum Mill.	-	-	-	-	-	14	-	-	14	-	-	6.6	-	-	-
Meliaceae	*Cedrela toona* Roxb. ex Willd.	-	-	-	-	-	-	-	-	15	-	-	-	-	-	-
	Melia azedarach Linn.	6.5	4.5	5	-	-	-	-	4.6	-	-	-	-	-	-	-
Carryophy-laceae	*Cerastium cerastoides* (L.) Britton.	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-
	Silene conoidea L.	-	-	-	-	-	-	-	-	1.5	3.5	-	-	-	-	-
Chenopodi-aceae	*Chenopodium album* L.	-	-	-	-	-	6.9	-	1.4	-	-	-	-	-	-	-
Ranuncu-laceae	*Clematis barbellata* Edgew.	-	-	-	-	-	2.6	-	-	-	-	-	-	-	5.6	4.9
Cyperaceae	*Cyperus compressus* Linn.	-	-	-	-	-	-	-	1.7	-	-	-	-	-	-	8.4
	Cyperus rotundus Linn.	-	-	-	12	-	-	-	-	-	-	-	-	-	6.5	-
	Carex filicina Nees.	-	-	-	-	-	-	-	-	4.3	-	-	-	-	-	-
Paplionaceae	*Dalbergia sissoo* Roxb.	-	49	12	62	22	46	17	32	25	30	26	41	14	7.1	12
	Medicago minima Linn.	7.2	5.8	4.9	-	4.3	8.1	-	5.3	8.3	-	-	-	-	-	-
Urticaceae	*Debregeasia salicifolia* D.Don.	14	-	13	7.3	-	-	-	-	-	-	-	-	-	-	-
Sapindaceae	*Dodonaea viscosa* (Linn.) Jacq.	-	-	-	-	28	-	-	-	23	-	23	17	36	28	-
Dryopteri-daceae	*Dryopteris ramosa* (Hope) C. Chr.	7.6	-	-	-	-	-	-	-	-	-	-	-	3.9	-	-

Family	Plant Species	Site Wise Importance Value Index														
	Dryopteris stewartii Fraser-Jenk	-	-	-	-	-	5.5	-	-	-	-	-	-	-	-	-
Elaeagnaceae	*Elaeagnus parviflora* Wall.	9	-	-	-	-	-	-	-	-	-	-	-	-	9.9	9.5
Equisetaceae	*Equisetum arvense* L.	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-
Myrtaceae	*Eucalyptus lanceolatus* Honey.	-	-	-	-	-	-	5.3	-	-	12	-	-	-	-	-
Euphorbiaceae	*Euphorbia hirta* L.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
	Mallotus philippensis (Lam.) Muell.	8.6	-	-	-	14	-	8.3	16	10	-	22	16	16	-	-
	Ricinus communis L.	-	-	17	-	5.1	49	12	-	-	23	-	34	-	-	9.6
Moraceae	*Ficus benghalensis* L.	-	-	-	-	-	-	-	-	-	13	-	-	-	-	-
	Ficus glomerata Roxb.	6.8	-	8.4	-	-	-	-	-	-	-	-	-	-	-	-
	Ficus palmata Forssk.	-	-	7.8	-	-	-	7.1	-	-	-	5.3	-	-	-	-
	Broussonetia papyrifera Vent.	7.9	3.5	-	5.3	3.6	-	-	-	-	-	-	5.2	-	-	6.3
	Morus alba L.	-	-	7.5	-	-	-	-	-	-	-	-	-	-	-	4.8
	Morus nigra L.	12	-	-	-	-	-	-	-	-	-	-	10	-	-	-
Tiliaceae	*Grewia optiva* Drummond ex Burret.	-	-	7.6	-	-	-	-	-	-	-	-	-	-	-	-
Convolvulaceae	*Ipomoea carnea* Parker.	-	-	-	20	-	19	-	-	-	27	-	-	16	-	-
	Ipomoea pentaphylla (Linn.) Jacq.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.9
Malvaceae	*Malvastrum tricuspidatum* R. Br.	-	-	-	5.5	5.8	7.4	6.4	5	-	4.1	4	-	-	-	-
	Malvestrum coromendelianum Linn.	10	5.1	-	-	-	-	-	-	6.5	7	-	3.9	7.9	5.6	-
	Bombax ceiba Linn.	-	-	-	-	-	-	5.2	-	-	-	-	-	-	-	-
Onagraceae	*Oenothera rosea* (L.) Her. ex Ait.	-	-	-	-	-	6.2	-	-	-	-	-	-	-	5.3	-
Oleaceae	*Olea ferruginea* Royle.	8.3	-	-	-	3.6	-	-	4.6	9.9	-	5.1	-	-	-	-
Cactaceae	*Opuntia dilleni* Haw.	4.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apiaceae	*Pimpinella acuminata* Edgew.	-	-	-	-	-	-	3.7	-	-	-	-	-	-	6.8	-
Pinaceae	*Pinus roxburghii* Sargent.	-	-	-	-	-	-	3.7	-	-	-	-	-	6.9	-	-
Polygonaceae	*Polygonum affine* D.Don.	-	-	-	-	8.9	-	-	-	-	3.2	-	-	-	3.9	-
	Polygonum aviculare Linn.	-	3.3	1.5	-	-	-	-	-	-	-	-	3.3	-	-	-
	Rumex dentatus Linn.	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Salicaceae	*Populus deltoids* Bartram ex Marsh.	-	-	-	8.2	-	-	14	-	-	-	-	-	-	-	-
	Salix alba Linn.	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Punicaceae	*Punica granatum* Linn.	21	-	-	11	-	-	-	-	-	-	-	-	-	-	-
Rosaceae	*Rosa brunonii* Lindl.	-	19	12	-	-	-	-	-	-	-	-	-	-	-	-
	Rubus fruticosus L.	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-
	Rubus hoffmeisterianus Kth. & Bch.	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cotoneaster microphylla Wall.	-	-	-	21	9.8	-	-	-	-	-	13	-	-	-	-
Solanaceae	*Solanum nigrum* L.	-	-	-	5.5	3.4	-	-	-	1.5	-	-	-	-	-	-

Family	Plant Species	Site Wise Importance Value Index														
	Solanum surattense Burm.	-	-	-	-	-	-	-	4.8	-	-	7.3	2.2	7.4	-	-
	Datura alba Rumphius ex Nees.	-	-	-	4.1	-	6.1	-	-	-	-	-	-	-	-	-
	Datura innoxia Miller.	2.3	3.3	-	-	4.1	-	1.7	-	-	-	-	5.6	-	-	-
	Physalis minima Roxb.	-	-	-	-	-	-	-	1.7	-	-	-	-	-	-	-
Asteraceae	*Sonchus arvensis* L.	-	-	-	-	-	-	-	-	1.5	-	-	-	-	-	-
	Sonchus asper L.	-	4.9	-	-	-	4.5	-	-	-	-	5.3	-	-	-	-
	Xanthium strumarium L.	4.5	6.3	10	-	6.9	11	5.4	3.8	7.5	8.4	13	9.7	13	8.3	-
	Parthenium hysterophorus L.	5	10	9.6	12	3.3	21	9.1	3.2	15	9.2	14	5.8	8.3	5.4	8.5
	Artemisia maritime (Huds.) L.	2.5	-	-	-	-	-	-	3.2	-	-	-	-	-	-	-
	Conyza bonariensis L.	-	3.3	-	-	3.5	2.3	-	-	-	-	-	-	3.9	-	-
Typhaceae	*Typha latifolia* L.	18	-	13	22	12	-	29	-	12	23	-	-	-	-	-
Ulmaceae	*Ulmus villosa* Brandis ex Gamble	-	8.4	9.3	-	-	-	5.2	-	-	-	-	-	-	-	-
	Celtis australis L.	-	3.4	-	-	-	-	-	4.6	-	-	5	-	-	-	-
Scrophulariaceae	*Verbascum thapsus* Linn.	1.2	12	-	-	-	-	1.7	-	-	-	-	-	5.2	-	-
Verbanaceae	*Vitex negundo* Linn.	18	13	14	-	15	9.8	18	-	-	28	-	9.7	-	-	5.6
	Lantana camara Linn.	-	18	-	-	20	-	-	-	-	9.6	-	7.5	-	-	13
Rhamnaceae	*Ziziphus mauritiana* Lam.	11	-	15	11	-	-	11	15	19	-	-	-	7.6	22	17
	Ziziphus oxyphylla Edgew.	-	-	14	14	-	-	-	9.7	-	-	-	-	-	-	-

3.2 Two-way clustering (vegetation classification)

To classify the vegetation types of Mahseer National Park AJK, a cluster analysis was conducted. Four clusters of fifteen sampling sites were identified on the basis of spatial variations in floristic composition and degree of closeness. These results were presented in a dendrogram Fig. 2.

Cluster-1, represented by a yellow colour in dendrogram, consists of 5 closely associated sites that are, ST-2, ST-4, ST-6, ST-12 and ST-10, constituting a total of 24.07 % of all species. This group was characterized by the presence of *Acacia modesta, D. sissoo, Olea ferruginea and Celtis australis* as prominent tree species, which were less frequent in these sites. Frequently distributed herbaceous plant species include *Solanum surattense, Amaranthus viridis, Parthenium hysterophorus, Cynodon dactylon,* etc., while shrubby flora includes *Dodonaea viscosa, Adhatoda zeylanica, Ziziphus mauritiana,* etc. These sites showed a relatively moderate level of disturbance.

Cluster-2, displayed in pink colour, consists of 6 sites which are closely associated with each other; they are ST-5, ST-9, ST-11, ST-15, ST-13 and ST-14 in Mahseer National Park, AJK. Sites categorized in this group were the most diverse and contributed the maximum number of plant species which was 44.44% of the total number of all plants. Tree layer in these sites includes *Acacia nilotica, Ficus benghalensis, Eucalyptus lanceolatus, Pinus roxburghii,* etc., while *Cotoneaster microphylla, Ricinus communis,*

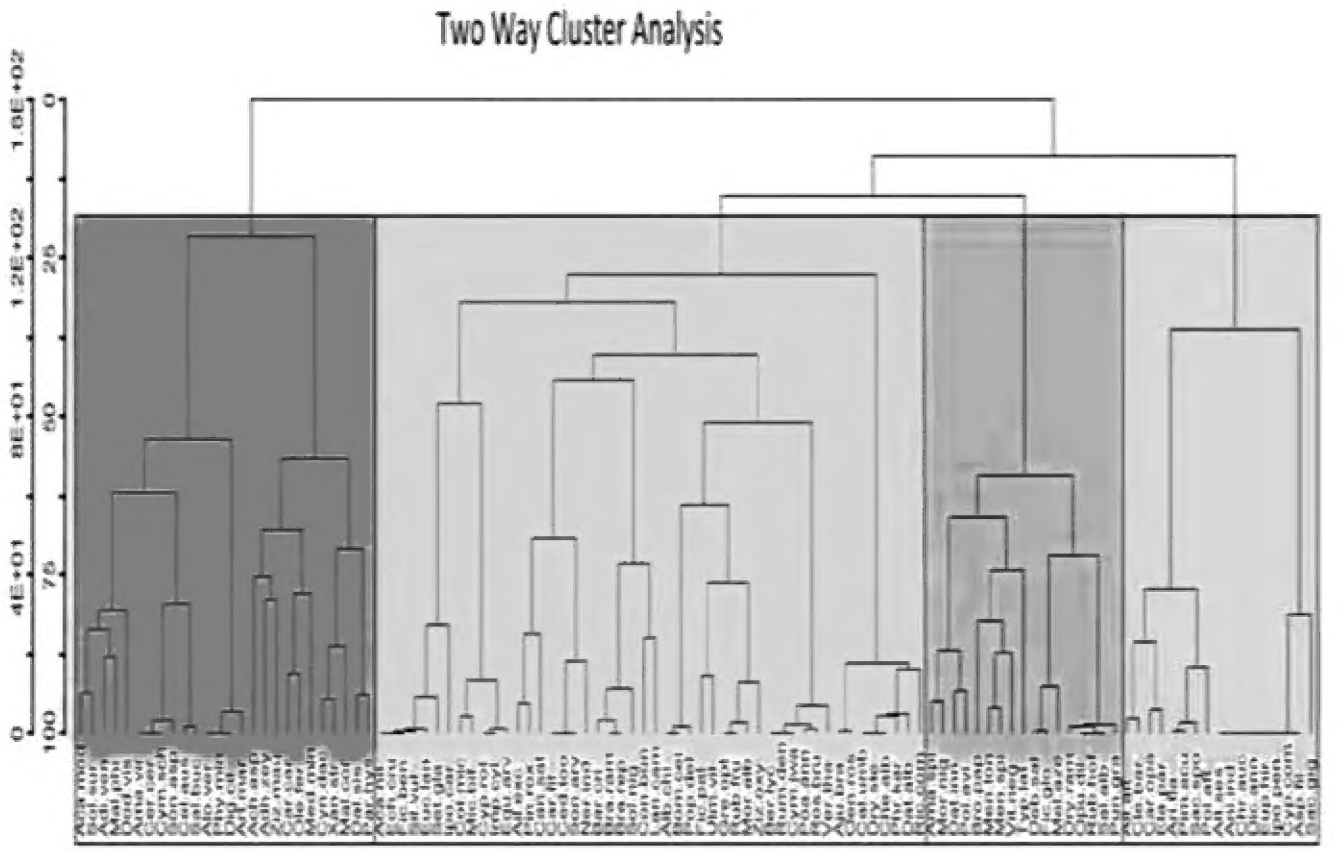

Figure 2. Two-way clustering for vegetation categorization of Mahseer National Park, AJK

Ziziphus oxyphylla, Berberis lycium, etc., was the most prominent shrubby vegetation. Both trees and shrubs were less in number while *Echinochloa crus-galli, Silene vulgaris, Sonchus arvensis, Rumex dentatus,* etc., were the abundant herbs of these sites. These sites were least disturbed from anthropogenic activities.

In light turquoise colour - Cluster-3 was characterized by the presence of *Morus nigra, Broussonetia papyrifera, Ficus glomerata. Melia azedarach,* etc., as major tree species. Herbaceous species such as *Amaranthus spinosus, Datura innoxia, Typha latifolia, Dryopteris ramosa,* etc., were dominant while *Punica granatum, Rubus hoffmeisterianus, Vitex negundo,* etc., were sparingly distributed shrubs in ST-3, ST-7 and ST-8. Sites categorized in this group were less diverse and exhibit few plant species - that is 15.74% of total flora of the area. These sites were highly disturbed by human and animal activities.

Cluster-4, represented by a Lavender colour in the diagram, consists of only ST-1 which was the least disturbed site by human beings and hence showed maximum diversity of plant species. A total of 15.74% flora was found to be present in this cluster. This group was characterized by the presence of *Ailanthus altissima* which was absent in other groups. *Euphorbia hirta, Dichantium annulatum, Asparagus filicinus and Ipomoea pentaphylla* showed sparse distribution.

Vegetation-environment correlation analysis

In order to understand the vegetation-environment relation in the study area, another multivariate technique - canonical correspondence analysis (CCA), was applied. Altitudinal gradient (Alt), moisture (Sat) %, colour, texture (Tex), pH, electrical conduc-

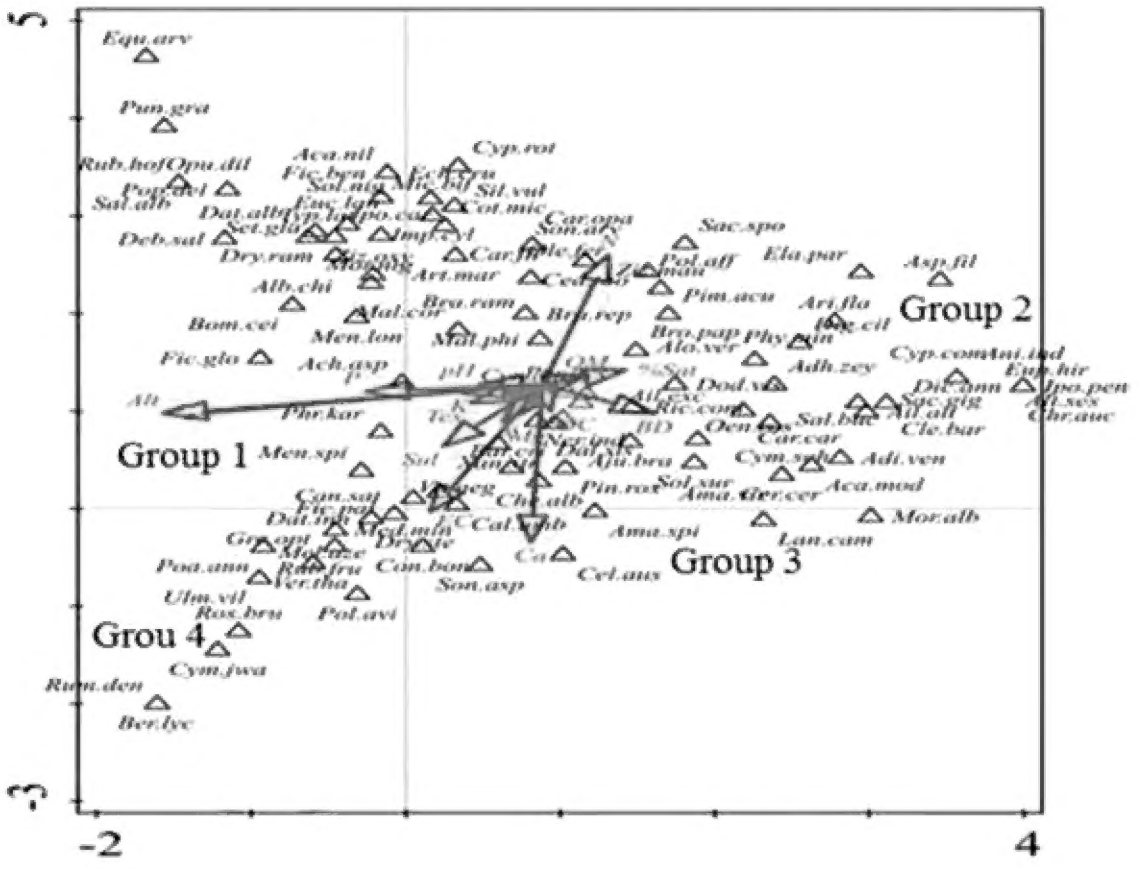

Figure 3. Biplot diagram of plant species and environmental variables along Mahseer National Park, AJK.

tivity (EC) (ds/m), bulk density (BD) (g/cm^3), organic matter (OM) %, organic carbon (OC) %, phosphorus (P) ppm, potassium (K) ppm, total nitrogen (N) %, calcium (Ca) (mg/l), magnesium (Mg) (mg/l) and sulphates (Sul) (mg/g) were entered as environmental variables in the CANOCO 4.5 software. CCA recognized four groups of flora which were influenced by different environmental factors Fig 3.

Results of the biplot diagram indicated that the plant species of Group 1 had the strongest correlation with altitudinal gradient while total soil nitrogen had significant correlation with the plant species of Group 2. Electrical conductivity and calcium portray a stronger correlation with the plant species of Group 3 as compared to various species of the other three groups. None of the environmental factors had any correlation with the plants of Group 4; however, EC portrays influence up to some extent in the distribution of species in this group. Presence of plant species near or beyond the tip of the arrows is strongly positively correlated as compared to those at the opposite which are less strongly affected by environmental variables.

General linear model response curve analysis

The response curve is actually a graphical illustration in CCA which exhibits a degree of plant response in relation to any environmental gradient. A general linear model curve was drawn for the plant species against the environmental variable which is altitude. *C. dactylon* was at peak in the response curve against the altitude, it showed gradual increase in response moving from high to low altitudes respectively. It was the most abundant species as it had an upper quartile of 55 at 1200 ft., median was 40

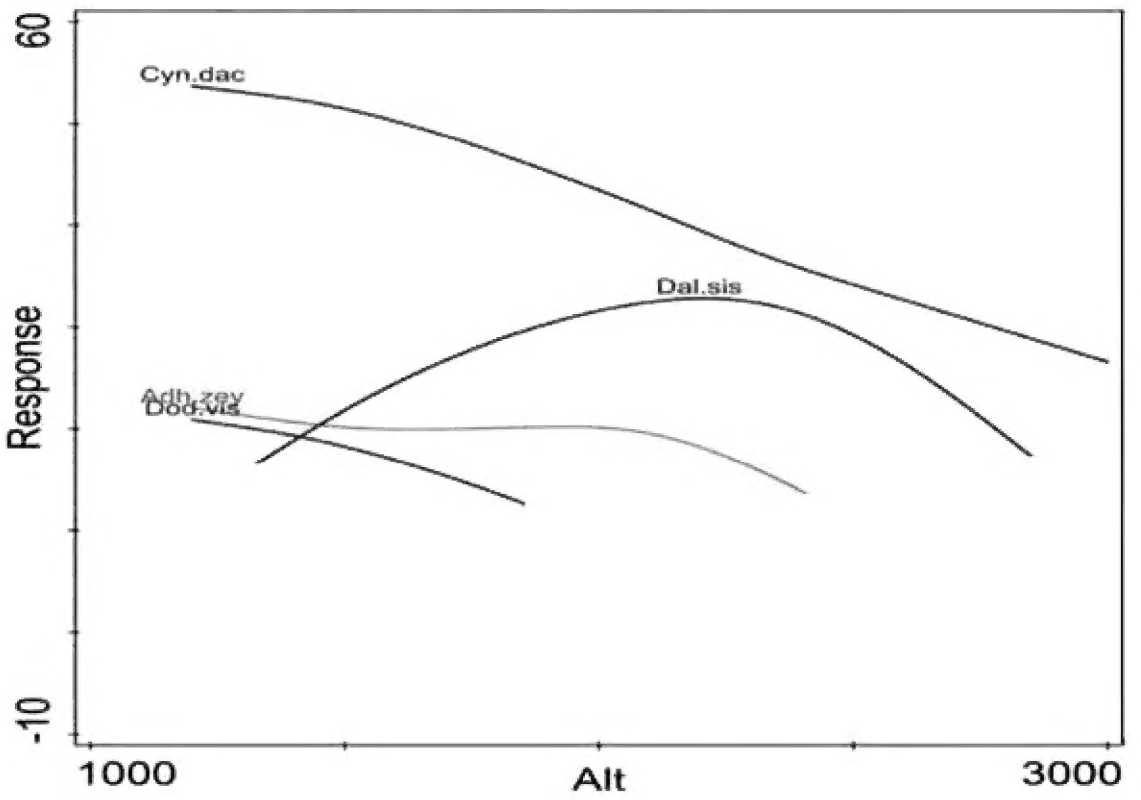

Figure 4. Linear model response curve of plant species against altitude.

at 2000 ft. while lower quartile 28 at an altitude of 3000 ft. *D. sissoo* held the second highest position, with an upper quartile 35 at an altitude of 2250 ft. while *A. zylenica featured* at number three with an upper quartile of 22 at 1200 ft. Fig. 4.

Discussion

The climate and vegetation of Mahseer National Park, AJK is mostly of subtropical nature except for a few sites. Marked differences in edaphic, and local climatic conditions support different plant communities in the area (Malik *et al.*, 2012). The abiotic factors, chiefly atmosphere, altitude, soil, etc., entirely control growth and existence of taxa and consequently quite an irregular pattern of vegetation dispersal was experienced in the study area. Almost all communities possess incomplete tree canopy layers. The floristic composition and distribution are mainly determined by natural site factors and only to a minor level by anthropogenic factors (Kumar *et al.*, 2010; Xu *et al.*, 2017; Zhang *et al.*, 2021)

In the current phytosociological assessment a total of fifteen sites from Mahseer National Park, AJK were explored at an altitude ranging between 1280 ft.-2847 ft. On the basis of IVI *Dalbergia sissoo* was the dominant tree species followed by *Adhatoda zeylinica* shrub, whereas the herb layer was ruled by *Cynodon dactylon*. Through minor deviance the current results are in accordance with those of Amjad *et al.*, 2017; Khan *et al.*, 2019; Hussain *et al.*, 2019.

The two way clustering classification technique has classified the vegetation of the study area into four major plant communities. There is a remarkable variation in the

vegetative cover. The upper most stratum was dominated by *D. sissoo, A. modesta, M. alba, F. palmata, A. altissima, B. papyrifera,* etc., while the middle stratum of shrubs was dominated by *Z. mauritiana, Z. oxyphylla, A. zeylanica, R. communis, C. carandas,* etc., at different elevations and aspects. The herb layer contained *C. dactylon, P. hysterophorus, C. sativa, X. strumarium* and *T. latifolia* as dominant plant species. With slight deviation, the present findings are in line with those of Ilyas *et al.*, 2015; Majeed *et al.*, 2022. The documented floristic composition of Mahseer National Park, AJK essentially revealed several remnants, i.e. ruined stages of key vegetation components as acknowledged by Ahmed *et al.,* 2015; Sen and Bhakat 2021.

The dispersal and structure of plant communities in the investigated site was influenced by multifaceted climatic aspects, e.g., environment, geographical features, soil and biotic impact. All of them experience ups and downs of different levels caused by their own interactions and hence result in micro-gradients (Ahmed *et al.*, (2009). The response of plant species towards environmental gradient and edaphic factors differed from species to species which was evaluated by a direct ordination technique.

CCA has categorized the flora of Mahseer National Park, AJK into four distinct groups. Topography, i.e. altitudinal gradient, imparts a greater influence as a climatic factor on structural physiognomies of vegetation existence and abundance in group 1 of the study area. Soil features influence plant distribution on a minor level, i.e. more local scale (Chauvier *et al.,* 2021). The plant species of group 2 had a significant correlation with total soil nitrogen while species categorized in group 3 gave a great response to Calcium contents of the soil and EC by showing growth and richness in phytodiversity. None of the environmental factors had any correlation with plants of group 4; however, EC portrays influence up to some extent, in the distribution pattern of species in this group. These findings are in agreement with the conclusions of Urooj *et al.* (2016).

In the current study a general linear model curve was drawn for the plant species of Mahasheer National Park, AJK against the environmental variable. which is altitude. *C. dactylon* was at peak in the response curve followed by *D.sissoo* and *A. zeylinica*. These results are closely associated with the studies of Khan *et al.* (2013) which was an analysis of vegetation dominance against moisture stress in Changa Manga forest. Their response curve shows *C. dactylon* as the dominant plant species followed by *D. bipinnata* and *C. Canadensis.*

Conclusion The present study clarifies that the environmental, as well as soil conditions are responsible for the recognition of different plant communities in the area. The distribution pattern of plant species is majorly influenced by an elevational gradient. However, there is an immense need of taxonomic description, complete geographic mapping, biomass estimation, etc., of the existing plant resources of Mahseer National Park, AJK. The present research would serve as baseline information for future researchers.

Conflict of interest

The authors have declared that there is no conflict of interests.

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